REVIEW

META-ANALYSIS OF THE DISTRIBUTION OF DAIDZEIN, GENISTEIN, GLYCITEIN AND THEIR GLUCOSIDIC CONJUGATES IN SOY FOODS *)

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ABSTRAK

Isoflavon dalam produk kedelai diduga memiliki peran penting dalam menurunkan kadar kolesterol darah dan mencegah pertumbuhan sel kanker. Namun seberapa banyak isoflavon dalam produk kedelai harus dikonsumsi per hari untuk mendapatkan dampak positif yang diinginkan masih belum banyak diketahui konsumen. Oleh karena itu makalah ini bertujuan menganalisa perubahan (meta-analisa) kadar isoflavon dan distribusi aglikon serta konjugatnya dalam berbagai pangan dari kedelai. Meta-analisa ini didasarkan pada delapan publikasi ilmiah yang melaporkan kandungan isoflavon total, aglikon (daidzein, genistein dan glycitein), dan konjugatnya (daidzin, genistin, glycitin, konjugat glukosida bergugus asetil maupun bergugus malonil) yang dinyatakan dalam berat bahan kering. Kadar isoflavon total dalam biji kedelai berkisar 0,47 s/d 4,22 mg/g berat bahan kering dengan nilai rerata 2,13 ± 0,88 mg/g (n = 34). Varietas, lokasi penanaman dan kondisi lingkungan sangat berpengaruh terhadap kadar isoflavon total dalam biji kedelai. Sebagian besar (80 s/d 97%) isoflavon dalam produk kedelai non-fermentasi berada dalam bentuk konjugat, sedangkan hanya sebagian kecil berada dalam bentuk aglikon. Sedangkan dalam produk kedelai hasil fermentasi proporsi isoflavon aglikon mengalami peningkatan dari 2,5% menjadi sekitar 60%. Pada umumnya kadar isoflavon dalam produk dari kedelai cenderung lebih rendah atau sama dengan yang terdapat dalam biji kedelai, tergantung pada cara pengolahan dan pangan yang ditambahkan.

INTRODUCTION

Soybeans have been consumed by Asians for centuries and played a significant role in Asian's daily menus. In 1991, Golbitz (1991) estimated that the annual per capita consumption of soybeans in China, Indonesia, Korea, Japan and Taiwan were 3.4, 6.3, 9.0, 10.8 and 13 kg, respectively. There are many types of soyfoods in the market all over the world. Some are produced by using sophisticated processing techniques to produce soy-based food ingredients such as soy protein concentrate and soy protein isolate, while others are produced by using traditional processing techniques. These soyfoods are typically divided into two categories. First, the nonfermented foods include fresh green soybeans, whole dry soybeans, soy nuts, soy sprouts, whole-fat soy flour, soymilk and its products, tofu, soy drink and meat analog. Second, the fermented foods include tempeh, miso, soy sauces, natto, fermented tofu and fermented soymilk products (Golbitz, 1995).

Soybean has also been acclaimed as a health food due to its high content of monounsaturated fatty acids, omega-3 fatty acids, fat soluble vitamins, minerals, soluble and insoluble fibers as well as phytochemicals such as isoflavones. Isoflavone has been intensively studied and evidence has shown that isoflavone possesses anticarnogenic effects by acting as antioxidants (Ikehata et al., 1968, Naim et al., 1976; Murakami et al., 1984), antiestrogens (Adlercreutz et al., 1986) and tyrosine protein kinase inhibitors (Akiyama et al., 1987). A comprehensive review of soy intake and cancer risk based on in vitro and in vivo data (Messina et al., 1994) and a meta-analysis of soy protein intake and its hypocholesterolemic effects have recently been published (Anderson et al., 1995).

Soybean seeds contain three types of isoflavones and each has four different chemical form: (1) the aglycons daidzein, genistein, and glycitein; (2) the glycosides daidzin, genistin, and glycitin; (3) the acetylglycosides 6"-*O*-acetyldaidzin, 6"-*O*-acetylgenistin and 6"-*O*-acetylglycitin; (4) the malonylglycosides 6"-*O*-malonyldaidzin, 6"-*O*-malonylgenistin and 6"-*O*-malonylglycitin (Kudou et al., 1991). Only small quantities of isoflavones (0.5 – 1.1%) present in the seed coat (hull) of soybeans. Most of the isoflavones (80.5 – 91.2%) are concentrated in hypocotyl, while the cotyledons contain approximately 8.2 – 18.3% of the total amount of isoflavones (Eldridge and Kwolek, 1983). Previous studies on isoflavone content in soybean and in soy foods have also indicated that not all of them seem to contain these 12 forms of isoflavones. However, most of these studies reported that the total isoflavones contents in soybean were approximately 1 – 3 mg/g dry soybean (Murphy, 1982; Eldridge, 1982; Eldridge and Kwolek, 1983; Wang et al.; 1990; Coward at al., 1993; Wang and Murphy, 1994a; 1994b).

Proposed anticarcinogenic doses of soy isoflavones range from 1.5 – 2.0 mg per kg body weight per day (Hendrich et al., 1994). For adults with 60 kg body weight it means 90 – 120 mg isoflavone intake per day.

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Depending on the isoflavone content in the soybeans, these levels equivalent to approximately 30 – 120 g of soybeans per day. On a body weight basis, this is comparable to the levels of isoflavones in powdered soybean chip-containing diets that inhibited the progression of mammary tumors in a *N*-methyl-nitrosourea-induced animal model of breast cancer in rats (Barnes et al., 1990). Other animal and human studies have also suggested that probably isoflavones be responsible for most of the hypocholesterolemic effect of soy protein (Walsh et al., 1991; Dwyer et al., 1994; Cassidy et al., 1994; Anthony et al., 1995a; 1995b). Anderson et al. (1995) reported that a significant reduction in serum cholesterol level was obtainable by consuming on average 47 g of soy protein. This amount is equivalent to approximately 141 g of soybeans. An individual with cholesterol level higher than 220 mg/dL may consume as low as 31 g of soy protein (equivalent to 93 g of soybeans) to achieve the same level cholesterol reduction.

Regarding the use of soy isoflavones to reduce cholesterol levels or to prevent carcinogenesis, the consumers have to be advised how much soy foods to be consumed per day. Given the wide variation of isoflavone contents in soy foods, further analysis on published literatures is necessary to obtain accurate estimates on soy isoflavones available for consumers. Therefore, this meta-analysis was intended to evaluate the effects of soybean varieties, growing conditions, type of processing, and fermentation on total isoflavones content and on the proportion of isoflavone aglycones and their conjugates in soy foods based on published literatures.

MATERIALS AND METHODS

Studies on isoflavone content in soybeans of different varieties, soy-based food ingredients and soy foods were searched from journals which were published up to the end of 1995. Studies were selected for further analysis if they reported the total isoflavone contents and isoflavone compositions including either aglycones such as daidzein, genistein and glycitein or glycosidic conjugates such as daidzin, genistin, glycitin and their corresponding acetylated as well as malonylated forms. Sixteen articles containing the above information were selected and used for further analysis. Isoflavone contents were recalculated and expressed as mg/g of soy material, as is; while the proportion of soy aglycones and glycosidic conjugates were calculated and expressed as percent of total isoflavones.

Summary results of the selected reports were tabulated and categorized for further analysis. The total isoflavone contents and its distribution were statistically analyzed. Estimates of the means of total isoflavone contents and the distribution of aglycones as well as their glycosidic conjugates were presented along with their standard deviations. Wherever appropriate, a 95% confidence intervals were used to determine significant differences of the estimated mean values.

RESULTS AND DISCUSSION

Data in Table 1 indicate the isoflavone and isoflavone glucoside contents of 18 varieties of soybeans grown in different places and at different years. Total isoflavone concentrations in various soybean varieties were in the range of 0.47 to 4.22 mg/g, with the average value of 2.13 ± 0.88 mg/g. A very small fraction of the soybean isoflavones (less than 2.78%) existed as aglycones such as daidzein, genistein and glycitein; whereas the majority (97.28%) of the soybean isoflavones were found in the form of glycosidic conjugates such as daidzin, genistin, glycitin, and their corresponding acetylated and malonylated forms. The distributions of isoflavone aglycones and their glycosidic conjugates were similar in all soybean varities. This indicates that variety, growing conditions and their interactions could significantly affect the total isoflavone contents. However, the proportions of isoflavone aglycones and their glycosidic conjugates in soybeans were remain unchanged. Genistin and its malonylated and acetylated forms were the most predominant (56.49 ± 12.64%) isoflavone glycosidic conjugates in all soybeans varieties, while daidzin and its malonylated and acetylated glycosidic conjugates comprising 30.66 ± 7.40% of total isoflavones. Fahmy et al. (1995) reported that isoflavone contents of soybeans grown in Egypt and Michigan (USA) ranged from 0.48 to 3.11 mg/g, with the average value of 1.58 mg/g. This findings are in close agreement with isoflavone contents in varieties of soybeans reported in previous studies (Eldridge and Kwolek, 1983; Wang and Murphy, 1994).

Isoflavone contents of soy-derived food materials such as soy flours, soy protein concentrates, and soy protein isolates are listed in Table 2. Soy flour is obtained by grinding dehulled soybeans following the removal of oil by solvent extraction. However, isoflavones were not found in soybean oil (Eldridge, 1982; Eldridge and Kwolek, 1983; Coward et al., 1993). Depending on the type of soy flours produced, the soy material is heated to varying degrees. However, no evidence was found that heating had a significant effect on total isoflavones, isoflavone aglycones, and their conjugated forms (Coward et al., 1993). The range of isoflavone concentrations in soy flours commercially available was 1.34 to 3.06 mg/g with the average value of 2.42 ± 0.46 mg/g. Approximately 85% of the total isoflavones in soy flours were found as glycosidic conjugates, while approximately only 15% of them existed as aglycones. This isoflavone distribution is similar to that of whole soybeans. Total isoflavones and the distribution of aglycones and glycosidic conjugates in soy flours are not significantly different ($P > 0.05$) to the levels found in whole soybeans.

Soy protein concentrate is prepared by extraction of white flakes or milled flour, depending on the method of extraction and drying system employed. The main objective in producing soy protein concentrate is to remove strong beany flavor and the flatulence sugars such as stachyose and raffinose. However, other soluble compounds including isoflavones are also partially co-extracted. As a result, its protein and dietary fiber contents are increased. Three different extraction methods can be used: extraction with aqueous ethyl alcohol (70 – 90%), extraction with water at isoelectric pH (4.5), and denaturing the protein with moist heat prior to extraction with water (Ohren, 1981; Soy Protein Council, 1987). When aqueous alcohol was used as extracting solvent, most of the isoflavones were leached out. This process resulted in soy protein concentrate with a minimal isoflavone contents. For example, isoflavone content of aqueous alcohol extracted soy protein concentrate could reach as low as 0.16 mg/g, while isoflavone content of water extracted soy protein concentrate could reach as high as 3.17 mg/g which is almost similar with the level found in whole soybeans (Table 2). This indicates that isoflavones have a low solubility in water.

Soy protein isolate is prepared by solubilizing the protein at pH 6.8 – 10 at 27 – 66°C by using sodium hydroxide and other food-grade alkaline agents. The protein solution is then separated from the flakes or flours by centrifugation. The solution is then acidified to pH 4.5 by using hydrochloric or phosphoric acid. Subsequently, the protein is prescipitated as a curd. The curd is then neutralized to pH 6.5 – 7.0 or spray dried in its acidic form (Lusas and Riaz, 1995). Isoflavone contents in soy protein isolates range from 0.62 to 1.45 mg/g and the average value of 1.49 ± 0.67 mg/g. This is slightly lower than the levels found in whole soybeans and soy flours (Table 2). The distribution of isoflavone aglycones and their corresponding glycosidic conjugates are remain the same as the isoflavones distribution existed in soybeans, soy flours and soy protein concentrates. This could be due to incomplete recovery of isoflavones from the soy flour during the alkaline extraction step. Selective precipitation of the isoflavone aglycones at pH 4.5 may also be responsible for the decrease of isoflavone contents. Acidic conditions, however, could hydrolize the glycosidic conjugates to produce isoflavone aglycones. This is also clearly indicated by the higher proportion of aglycones found in the soy protein isolates as compared to soy flour or soy concentrates.

Nonfermented soy foods such as tofu, soy milk and soy beverages are widely consumed in Asian countries and becoming increasingly popular in Western countries. The isoflavone contents of soy foods are presented in Table 3. Some soy foods such as dry spiced tofu, soy milk skin/film and soy beverages contain isoflavone as high as 2.11 mg/g, while tofu and soy milk contain even less isoflavones (0.22 – 0.53 mg/g). Soy hot dog and soy bacon are prepared using soy protein isolate containing high levels of isoflavones. During preparation, however, it is often diluted with the addition of other food ingredients containing no isoflavone. In nonfermented soy foods, the isoflavones are present mainly (not less than 70%) as glycosidic conjugates. Interestingly, when soy milk skin, dry spiced tofu and hard tofu are contaminated by micro-organisms for certain periode of time, the proportion of isoflavone aglycones increases. On the other hand, in fermented soy foods the majority of isoflavones are present as aglycones (approximately 60%). Total isoflavone contents of fermented soy foods are in the range of 0.362 to 0.920 mg/g with the average value of 0.58 ± 0.20 mg/g, except soy sauce which contains only trace levels of isoflavones (0.02 mg/g).

The isoflavone levels in soy sprouts obtained commercially are varied. This variability seem to be affected by stage of growth and storage conditions. The increase of isoflavone contents with the longer germination time may suggest that isoflavones biosynthesis is still in progress (Table 4). Wang et al. (1990) indicated that daidzin concentrations in soy seeds steadily increase from 42.99 to 54.25% during a 10-day germination periode. Only slight changes on genistein levels were noted during germination, while the levels of genistin decreased during germination time. Although daizein and coumestrol levels were also increase during germination period, however, these only account for less than approximately 4% of total isoflavones in soy sprouts.

CONCLUSION

Isoflavones contents in soybeans are affected by varieties and growing conditions. Therefore, isoflavones levels in soybeans ranges from as low as 0.47 to 4.22 mg/g with the average value of 2.13 ± 0.88 mg/g (n = 34). Depending on the types of processing involved and levels of soy materials used, the isoflavones contents in soy materials and soy foods are at best the same as or usually lower than that of whole soybeans. The majority of isoflavone isomers present in soybeans, soy flours, soy protein concentrates, and soy protein isolates are in the form of glycosidic conjugates (approximately 80 to 97%) such as daidzin, genistin, glycitin and its acetylated or malonylated forms. The proportions of isoflavone aglycones (daidzein, genistein and glycitein) in soy foods increases from as low as 2.5% to approximately 60% when these soy foods were prepared using acidic treatments or fermentation. Given the wide variation of isoflavone contents in soybeans, soy materials and soy foods (from 0.02 to 4.22 mg/g), consumers should be provided with more accurate estimates of isoflavone content of every soy food category.

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Tabel 1. Distribution of daidzein, genistein, glycitein and their corresponding glycosidic conjugates in various soybean varieties

Soybean Variety	Study (Ref.)	Aglycones			Conjugates*			Total Isoflavone (mg/g dry matter)
		daidzein (%)[a]	genistein (%)[a]	glycitein (%)[a]	daidzin (%)[a]	genistin (%)[a]	glycitin (%)[a]	
Amcor	1	0.53	1.67	0.87	25.90	64.29	6.61	1.498
Amsoy	1	1.10	1.45	0.61	55.86	6.33	34.58	1.925
Century	1	1.20	1.84	0.88	33.9	56.16	6.04	2.502
Clark (IL, 1975)	1	0.90	0.27	1.18	29.60	60.15	7.81	2.547
Clark (IL, 1976)	1	0.22	0.25	0.88	34.32	58.04	6.29	3.625
Clark (IL, 1978)	1	0.39	0.07	0.67	34.64	55.25	8.95	2.849
Clark (IL, 1979)	1	0.49	0.24	0.82	33.69	55.22	9.58	2.452
Corsoy-79 (Girard, IL)	1	3.00	1.00	0	31.41	49.44	15.27	0.799
Corsoy-79 (Urbana, IL)	1	1.94	0.39	0	31.78	57.48	8.41	1.545
Corsoy-79 (Pontiac, IL)	1	0.97	0.20	0	32.85	59.25	6.82	1.951
Corsoy-79 (Dekalb, IL)	1	1.83	0.52	0	27.92	59.66	9.95	1.909
Hardin (Urbana, IL)	1	1.73	2.76	1.90	26.32	58.67	8.20	1.159
Hardin (Girard, IL)	1	2.34	1.92	0	30.28	45.84	19.62	0.469
Hardin (Urbana, IL)	1	0.61	0.07	0	27.54	61.08	9.06	0.817
Hardin (Pontiac, IL)	1	1.28	0.02	0	29.08	61.69	8.39	1.561
Hardin (Dekalb, IL)	1	1.23	0.03	0	26.00	62.94	9.43	1.708
Keburi (1991)	2	0.04	0.38	0.90	28.38	60.22	10.07	2.343
Keburi (1992)	2	0.28	0.57	1.35	29.62	57.26	10.84	1.411
Kuro diazu (1991)	2	0	0.39	0	22.34	66.68	10.48	2.041
Kuro diazu (1992)	2	0	0.55	0.95	20.54	67.01	10.86	1.261
Raiden (1991)	2	0	0.48	0.95	22.73	61.95	13.84	2.305
Raiden (1992)	2	0	0.56	1.41	20.82	61.75	15.38	1.417
Pioneer 9111	2	0.66	0.71	0.45	31.47	62.76	3.91	4.216
Pioneer 9202	2	0.60	0.89	0.52	30.50	62.37	5.07	3.806
Prize	2	0.97	0.85	0.51	38.32	55.30	3.99	3.886
HP204	2	0.19	0.73	0.92	26.55	62.15	9.40	2.053
LS301	2	0.28	0.45	0.53	33.62	59.72	5.32	3.551
XL72	2	0.54	2.04	0.95	15.72	69.29	11.45	2.201
Strayer 2233	2	1.07	1.28	0.85	32.08	56.61	8.06	2.344
Sprite	2	1.03	1.20	0.97	27.06	64.82	4.91	3.093
Tiger	2	1.02	1.81	0.62	49.95	12.74	33.84	1.744
Vinton 81 (1989)	3	1.78	1.69	0.60	35.93	54.70	5.26	3.309
Vinton 81 (1990)	3	0.94	1.04	0.72	35.66	57.78	3.82	2.776
Vinton 81 (1991)	3	1.09	1.28	1.53	29.94	55.92	10.24	1.563
Average ± std. dev.		1.01±0.67	0.87±0.68	0.90±0.34	30.66±7.40[b]	56.49±12.64[b]	10.34±6.99	2.13±0.88[b]

a : Calculated as percent of total isoflavones
b : Significantly different from zero ($P < 0.05$)
1 : Eldridge and Kwolek, 1983; 2 : Wang and Murphy, 1994a; 3 : Wang and Murphy, 1994b
* : Including glycosides, acetylglycosides and malonylglycosides.

Tabel 2. Distribution of daidzein, genistein, glycitein and their corresponding glycosides in various soy-based food materials

Soybean Variety	Study (Ref.)	Aglycones			Conjugates*			Total Isoflavone (mg/g dry matter)
		daidzein (%)[a]	genistein (%)[a]	glycitein (%)[a]	daidzin (%)[a]	genistin (%)[a]	glycitin (%)[a]	
Soy flour :								
Soy flour	1	0.20	1.09	0.94	20.26	71.05	6.45	2.01
Soy four	2	0	1.12	0	43.50	55.38	0	1.34
Soy flour (Nutrisoy)	2	1.23	1.27	0	43.35	54.07	0	2.68
Soy flour (Nutrisoy 7B)	2	1.74	2.10	0	44.00	52.16	0	2.53
Soy flour (baker's)	2	0.79	1.00	0	43.78	54.41	0	2.39
Soy flur (toasted)	2	1.56	1.72	0	42.68	54.08	0	2.56
Amsoy variety	2	16.27	13.56	0	21.02	43.05	6.10	2.95
Nutrisoy 7B	3	3.81	1.90	0.95	29.05	58.57	5.71	2.10
Unflavored (TVP)	3	12.09	6.86	0.98	25.16	47.71	7.19	3.06
Textratein	3	16.14	16.14	0	21.40	41.75	4.56	2.85
Centex 300	3	15.72	11.79	1.31	21.40	44.54	5.24	2.29
Centex 300 SL	3	17.41	10.67	1.12	30.90	32.58	7.30	1.78
Centex 400	3	8.72	10.77	0	24.61	50.26	5.64	1.95
Centex 400 SL	3	10.82	8.52	0	25.25	50.49	4.92	3.05
Mira Tex	3	15.20	12.84	0	21.96	47.97	2.03	2.96
Promote III SL	3	10.80	10.00	0	24.80	51.60	2.80	2.50
Texturized Veg. Prot.	1	0.52	1.26	1.09	34.29	49.93	12.90	2.29
Texturized Veg. Prot.	1	0.35	0.97	1.15	36.40	51.44	9.69	2.26
Average ± std.dev.		7.41±6.65	6.31±5.27	0.42±0.53	30.77±8.97[b]	50.60±7.67[b]	4.47±3.59	2.42±0.46[b]
Soy concentrates :								
Soy concentrate	3	1.47	1.24	0	44.43	52.86	0	2.66
Response (alcohol ex.)	3	52.38	4.76	4.76	14.29	19.05	4.76	0.21
Food prot. conc.	3	8.10	8.91	0	23.89	50.20	8.91	2.47
ProCon 2000 (alcohol ex.)	3	27.91	2.32	0	20.93	44.19	4.65	0.43
Promosoy 100 (alcohol ex.)	3	12.50	12.50	6.25	25.00	37.50	6.25	0.16
GL-301	3	3.47	6.94	1.26	23.97	60.25	4.10	3.17
Arcon F (alcohol ex.)	2	2.52	2.52	0	40.25	54.72	0	0.16
Arcon S (alcohol ex.)	2	10.16	15.57	0	23.02	51.24	0	0.44
Average ± std.dev.		14.81±16.25	6.84±4.84	1.53±2.36	26.97±9.46[b]	46/25±12.11[b]	3.58±3.10	1.21±1.22
Soy protein isolates :								
Edi Pro N	3	6.78	18.64	1.69	13.56	56.78	2.54	1.18
Edi Pro A	3	11.65	12.62	0.97	13.59	57.28	3.88	1.03
Supro 610	3	12.41	12.41	1.38	15.86	55.17	2.76	1.45
Supro 620	3	9.52	4.76	0.95	19.05	62.86	2.86	1.05
Supro 710	3	15.91	12.88	2.27	22.73	41.67	4.54	1.32
Soy isolate	2	8.60	12.38	0	27.36	50.71	0	0.85
Soy isolate	2	8.81	16.32	0	24.01	50.86	0	1.16
Soy isolate	1	10.14	21.90	8.53	4.19	38.16	17.07	0.62
Soy isolate	1	1.11	3.65	2.53	18.24	61.19	13.27	0.99
Soy isolate	1	1.21	3.64	2.22	19.01	60.57	13.35	0.99
Average ± std.dev.		8.61±4.41	11.92±5.95	2.05±2.32	17.76±6.18[b]	53.52±7.84[b]	6.03±5.83	1.06±0.22[b]
Other soy materials :								
Soy nuts	2	2.28	2.79	0	36.01	58.82	0	2.36
Soy powder	2	0	0.80	0	33.29	65.67	0	1.75
Soy granule	1	0.50	1.12	0.91	37.64	49.83	9.98	2.40
Defatted soymeal	3	8.22	4.36	0	39.29	48.12	0	1.29
Defatted soymeal	3	9.13	4.32	0	36.55	50.00	0	1.37
Soy fiber	2	17.21	23.08	0	28.54	31.17	0	0.49
Soybean chips	2	8.10	6.48	0	41.27	44.39	0	0.80
Average ± std.dev.		6.49±5.65	6.13±7.16	0.13±0.32	36.08±3.86[b]	49.71±10.09[b]	1.43±3.49	1.49±0.67[b]

a : Calculated as percent of total isoflavones
b : Significantly different from zero ($P < 0.05$)
1 : Wang and Murphy (1994a); 2: Coward et al. (1993); 3: Eldridge (1982)
* : Including glycosides, acetylglycosides and malonylglycosides.

Tabel 3. Distribution of daidzein, genistein, glycitein and their glycosidic conjugates in various soy foods

Soybean Variety	Study (Ref.)	Aglycones			Conjugates*			Total Isoflavone (mg/g dry matter)
		daidzein (%)[a]	genistein (%)[a]	glycitein (%)[a]	daidzin (%)[a]	genistin (%)[a]	glycitin (%)[a]	
Nonfermented :								
Hard tofu	1	20.63	20.39	0	16.25	42.72	0	0.456
Soft tofu	1	13.08	9.23	0	26.44	51.25	0	0.649
Dry spiced tofu	1	27.46	37.22	0	10.09	25.23	0	2.115
Soy milk skin	1	20.89	29.44	0	15.07	34.59	0	1.305
Soy milk	1	9.95	12.92	0	48.72	28.41	0	0.222
Soy milk	2	4.36	2.78	0	40.87	51.59	0	0.252
Soy milk film	1	19.64	26.73	0	16.08	37.55	0	1.367
Tofu	2	3.84	7.43	0	29.02	59.71	0	0.417
Tofu	2	8.65	9.77	2.25	36.09	36.27	6.95	0.532
Tofu	3	3.04	3.04	0	40.49	54.45	0	0.494
Roast soybeans	3	1.46	2.59	1.95	33.90	50.99	9.09	2.661
Soy beverage (powder)	3	2.35	4.15	3.13	29.36	56.74	8.96	1.662
Soy beverage (powder)	3	0.91	2.31	1.22	28.61	57.64	9.31	1.643
Soy beverage (powder)	3	0.92	1.97	1.23	33.15	53.91	9.36	1.623
Soy beverage (powder)	3	1.56	2.61	1.09	33.10	53.70	7.92	1.918
Soy hot dog	3	3.39	6.78	3.39	19.91	47.88	18.64	0.236
Soy bacon	3	18.05	33.33	6.25	0	24.30	18.05	0.144
Flat noodle	3	0	10.24	14.96	11.81	33.86	29.13	0.127
Soy cheese	3	2.00	4.00	0	42.00	56.00	0	0.050
Soy cheddar cheese	3	0	4.57	4.06	42.13	26.90	8.63	0.197
Soy mozzarella cheese	3	0	6.50	7.32	19.51	39.24	27.64	0.123
Average ± std.dev.		9.01±8.44	11.24±10.64	2.97±4.85	28.63±11.10[b]	44.50±11.57[b]	7.31±8.95	0.83±0.78
Fermented :								
Tempeh	2	26.28	38.14	0	9.30	26.28	0	0.430
Tempeh	3	15.84	22.31	2.77	30.98	26.47	1.62	0.865
Tempeh burger	3	8.81	24.87	4.66	15.80	41.19	4.66	0.386
Miso	2	37.50	54.02	0	3.80	4.67	0	0.920
Honzukuri miso	3	8.74	23.91	3.86	18.77	34.44	3.86	0.389
Rice miso	2	17.57	33.66	0	0	49.01	0	0.404
Barley miso	2	25.65	33.15	0	19.69	21.50	0	0.721
Shiromiso soup mix	2	15.25	24.01	0	23.02	37.71	0	0.708
Akamiso soup mix	2	15.42	19.61	0	28.80	36.17	0	0.882
Soybean paste	2	34.56	44.03	0	7.72	13.68	0	0.570
Soybean paste	3	41.89	28.28	8.35	0.15	15.15	6.18	0.647
Soybean paste/rice	2	28.45	29.83	0	23.48	18.23	0	0.362
Soybean paste/wheat	2	24.25	28.64	0	21.71	25.40	0	0.433
Soy sauce	2	60.87	39.13	0	0	0	0	0.023
Fermented bean curd	3	36.76	57.33	5.91	0	0	0	0.389
Average ± std.dev.		26.52±13.64	33.39±10.93[b]	1.70±2.65	13.55±10.77	23.33±14.43	1.09±1.99	0.58±20.20[b]

a : Calculated as percent of total isoflavones
b : Significantly different from zero ($P < 0.05$)
1 : Wang at al. (1990); 2 : Coward et al. (1993); 3: Wang and Murphy (1994a)
* : Including glycosides, acetylglycosides and malonylglycosides.

Tabel 4. Distribution of daidzein, genistein, glycitein and their corresponding glycosides in soy sprout germinated for various times[a]

Germination time (day)	Aglycones			Conjugates[*]			Total Isoflavone (mg/g dry matter)
	daidzein (%)[b]	genistein (%)[b]	coumestrol (%)[b]	daidzin (%)[b]	genistin (%)[b]	coumestrol (%)[b]	
0	0.46	0.37	0	42.99	56.06	0.12	1.664
1	0.68	0.69	0.04	41.85	56.68	0.95	1.570
2	0.45	0.21	0.07	44.38	54.79	0.16	1.926
3	0.51	0	0.34	43.26	55.44	0.43	1.906
4	1.18	0.30	0.57	47.45	49.56	0.92	1.762
5	1.10	0.39	0.79	47.18	49.26	1.26	1.931

a : Data obtained and calculated from Wang et al. (1990)
b : Calculated as percent of total isoflavones
* : Including glycosides, acetylglycosides and malonylglycosides.